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MEMORANDUM

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DEVELOPMENT AND TESTING OF THE SOLAR CONTROL CORPORATION  
MODULAR CONTROLLER AND SOLARSTAT SUBSYSTEM --  
FINAL REPORT

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Solar Energy

## TABLE OF CONTENTS

	Page
SUMMARY .....	1
INTRODUCTION .....	1
Program Background and Goals .....	1
Purpose of this Product Development Contract .....	2
DESCRIPTION .....	2
Project Development Requirements and Criteria.....	2
77-171 Basic Module Controller .....	3
General Specifications .....	3
Standard Features .....	5
Optional Features.....	6
Control System Functions .....	6
Control System Arrangements.....	7
77-180 Solid State Solar System Monitor (Solarstat) .....	7
Specifications.....	7
CONCLUSIONS AND RECOMMENDATIONS .....	9
APPLICABLE DOCUMENTS .....	10

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## TECHNICAL MEMORANDUM

# DEVELOPMENT AND TESTING OF THE SOLAR CONTROL CORPORATION MODULAR CONTROLLER AND SOLARSTAT SUBSYSTEM--FINAL REPORT

## SUMMARY

This report is intended to provide product development information as an aid to the solar systems building industry in their effort to determine the products suitability for use in a specifically configured total solar heating and/or cooling system in residential and commercial dwellings.

This report will also serve as an aid to those who desire to remain abreast of the state-of-the-art of solar energy heating and cooling projects.

## INTRODUCTION

### Program Background and Goals

Prior to dealing with the specific aspects of the Solar Control Controller and Solarstat, a few background statements are pertinent. The problems of energy availability and increasing costs have led to a major national effort to develop alternate energy sources. One such source is the energy in solar radiation, which can be used for heating and cooling buildings, domestic hot water, and other applications. The National Energy Policy, as established in the Solar Heating and Cooling Demonstration Act of 1974 (PL93-409), provided for the demonstration of the practical use of solar heating technology within a 3-year period, and demonstration of the practical use of combined heating and cooling technology within a 5-year period. Responsibility for implementing the Demonstration Act was given to the Energy Research Development Administration (now the Department of Energy). The National Aeronautics and Space Administration (NASA), George C. Marshall Space Flight Center (MSFC) manages part of this work.

## **Purpose of this Product Development Contract**

The purpose of this contract was to provide funding to the Solar Control Corporation to do additional design, development and testing on their existing subsystems (Controller and Solarstat) so that each subsystem is classified as a reliable marketable product for public use.

The contract performance period began October 26, 1976 and lasted approximately one year.

## **DESCRIPTION**

### **Project Development Requirements and Criteria**

During the development of the Controller and Solarstat, the contractor was required to:

- 1) Meet the applicable parts of the interim performance criteria for solar heating and cooling systems.
- 2) Meet the subsystems performance specifications.
- 3) Provide test data/analysis to verify that hardware meets the subsystem performance specification.
- 4) Provide drawings and specifications in sufficient detail to define the configurations and to assure manufacturing repeatability.
- 5) Provide installation, operation, and maintenance instructions.
- 6) Provide program execution plans, design review data, periodic status reports, and acceptance data packages.
- 7) Provide subsystem and/or component hardware certification by an independent test laboratory (such as Underwriters Laboratory and American Gas Association) to meet nationally recognized standards and codes (such as American Society of Heating, Refrigeration and Air Conditioning Engineers; American Society for Mechanical Engineers; American Standards Institute and American Refrigeration Institute).

## 77-171 Basic Module Controller

The 77-171 Basic Module Controller is essentially a differential thermostat which is capable of controlling the operation of a solar heating and/or cooling system. The basic module may be used individually or may be combined with other basic modules to perform a variety of control functions as required for individual systems, such as pre-heat for domestic hot water, operation of airflow to equalize temperatures and others. The controller is a solid state device with relay output, permitting its use for a variety of control purposes according to the requirements of various systems. The controller's two temperature sensors are placed at the locations where temperatures are to be compared, such as the solar collector and the thermal storage. See Figure 1 for picture illustration of the Basic Module Controller.

### General Specifications

The basic module 77-171 general specifications are as follows:

Input Voltage	Either 120 Vac $\pm$ 10 V or 24 Vac $\pm$ 4 V
Input Power	3 W (no-load)
Outputs	DPDT (3PDT available)
Output Current	10 amp (resistive) at 28 Vac or 120 Vac (higher ratings available)
Output Voltage	Either 120 Vac or 24 Vac
Sensors	Matched thermistors, ( $+1^\circ$ C over range from $0^\circ$ C to $+100^\circ$ C) in a metal housing with high temperature teflon leads
Differential Turn off Offset	Typically $4^\circ$ F $\pm 2^\circ$ at $100^\circ$ F (can be custom adjusted by a resistor change)
Differential Turn on Offset	Typically $20^\circ$ F $\pm 2^\circ$ at $100^\circ$ F (can be custom adjusted by a resistor change)
Operating Temperature Range	Controller chassis: $-40^\circ$ F to $140^\circ$ F Sensors: $-40^\circ$ F to $300^\circ$ F
Tracking Accuracy	$\pm 5^\circ$ F over entire operating range
Isolation Protection	1500 V
Size	Basic Module approximately 4 x 4 x 3-1/2 in.

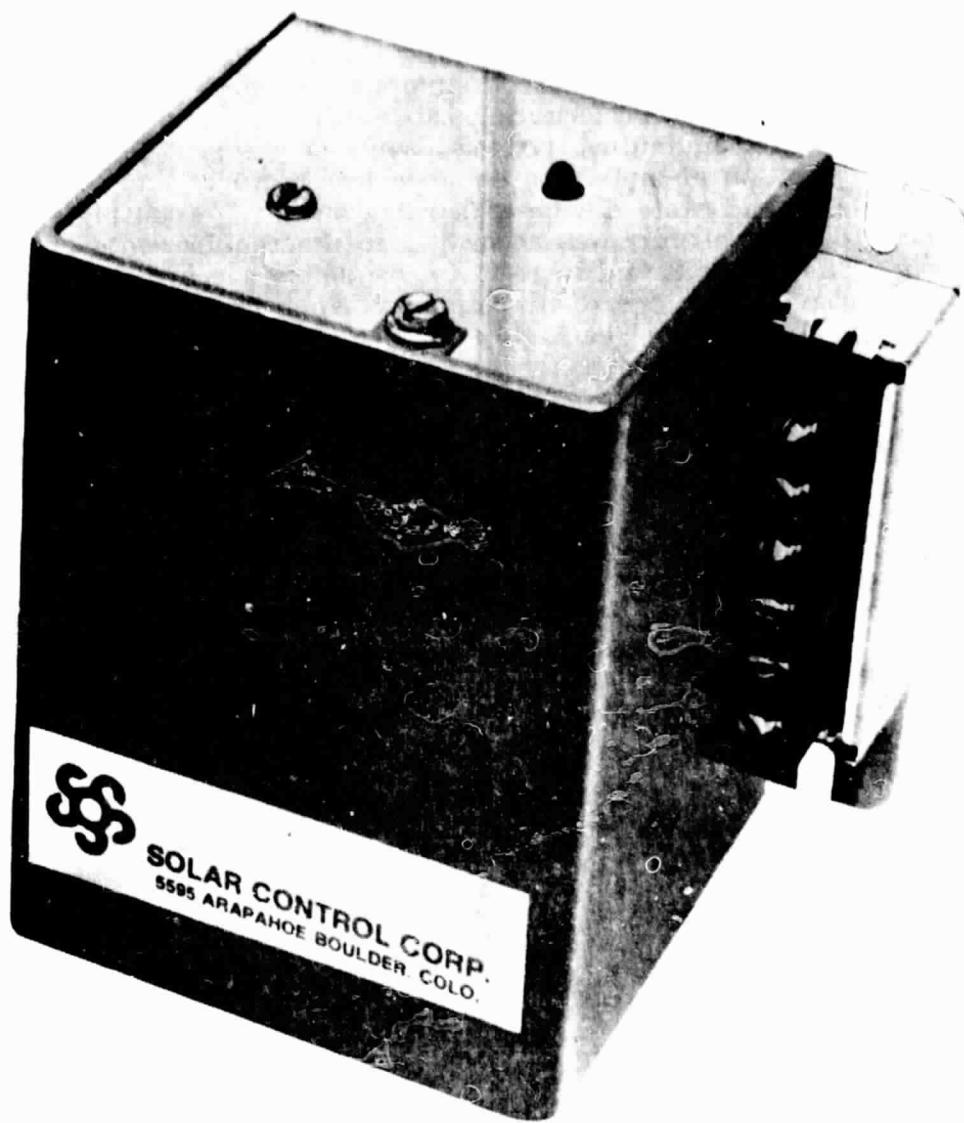


Figure 1. Basic modular controller.

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Weight	Less than 2 lb
Multichannel Priority	24 Vac interconnect logic
Mounting	Mount on "J" box or on wall or pump housing
Collector freeze protect (differential signal "on" typically; remote signal also available)	At 40°F $\pm$ 5°
Manual "on" Button	
Operating Light	100,000 hr LED illuminates to indicate operation
Distribution Channel and Auxiliary Heater Control	For 77-172, 77-173 configuration
Multi-Tank Control	For 77-175 configuration

### Standard Features

The basic module 77-171 is designed to include the following standard features:

- 110 Vac input
- 100 percent solid state circuits
- Multi-output relays
- Manual ON button permits quick check of controller operation
- Active filtering to reject noise
- Optimum hysteresis to eliminate switching chatter
- High impedance temperature sensors for accurate temperature sensing
- Boil-protection
- Freeze-protection features
- Easy installation
- Non-shorting terminal hookups

Screw-type terminals

Flying power leads for junction box terminals

Rugged, electrically insulated unit

Designed to UL specifications and to the National Electric Code

## Optional Features

The following optional features can be obtained on the basic module:

Low voltage input

Custom setting of distribution temperature

Freeze and/or boil protect features can be eliminated if necessary

Custom thermostats

## Control System Functions

Several control functions are possible through the use of the 77-171 basic module when put in a group configuration. Some of the control functions possible are as follows:

Additional temperature channels

Additional thermostat and distribution channels for multiple space use

Additional control for multi-storage systems

Auxiliary heater boost mode

Air conditioning control mode

Heat pump control mode

"Thermal equalizer" mode for circulation of air to eliminate heat-layering

## Control System Arrangements

The 77-171 modules can be connected to one another with appropriate priorities to provide complete control system packages. The control system can interface with multi-stage thermostats, auxiliary heaters, and distribution channels as needed. For example:

Thermostat Input with:

- a) Auxiliary Heat Enable
- b) Programmed delivery temperature

Distribution Channel and  
Auxiliary Heater Control

For 77-172, 77-173 configurations

Multi-Tank Control

For 77-175 configuration

For your specific configuration, contact the Solar Control Corporation for information.

## 77-180 Solid State Solar System Monitor (Solarstat)

The model 77-180 is a solid state temperature and system function monitor that provides the system owner with accurate outdoor, indoor, collector and storage temperature readings.

The outdoor temperature is continuously indicated by a 0.3 in. liquid crystal display. Collector and storage temperatures may be selected by depressing the appropriate button located on the Solarstat. The control thermostat provides room temperature as well as two stage signals to the solar system and auxiliary heating system.

The solar systems current mode of operation will be indicated by three light emitting diodes which give a bright red, indication of solar collection, solar distribution or auxiliary heating function.

The Solarstat uses less than 10 W at 24 Vac and is compatible with all conventional HVAC equipment. See Figure 2 for an illustration of the Solarstat.

## Specifications

Input voltage	24 Vac $\pm$ 20 percent
Input power	10 W maximum
Temperature sensors	Diodes, linear from $-40^{\circ}$ to $+199^{\circ}$ F



Figure 2. Solarstat.

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Displays	Temperature: 0.3 in. liquid crystal, 3 digits plus (-) sign. Mode of operation: 3 light emitting diodes.
Display range	Temperature -40° to +199°F
Accuracy	+ 0.5 percent or one count on least significant digit.
Measurement points	Outdoor, collector, storage and room.
Thermostat	Two stage heating. Optional two stage heating, one stage cooling and fan on/off.
Solarstat operating temperature	32° to 120°F
Size	8 x 7-1/4 x 2-1/8 in.
Weight	2 lb

## CONCLUSIONS AND RECOMMENDATIONS

No major problems were encountered during this contract. Two design changes were made to enhance marketability and simplify installation: (1) the input power was changed to 120 Vac, with 24 Vac optional and (2) the use of a unitized, rugged housing.

Two of the subsystems (Controllers with Solarstat) have been successfully deployed on two MSFC managed solar projects; (1) Operational Test Site (Single Family, Solar Heating and Hot Water System) and (2) Solar Demonstration Facility (Solar Hot Water System).

The Model 77-171 Controller was put on the market near the completion of the contract (late 1977); thus accomplishing the purpose of the contract.

Solar Control Corporation, Bolder, Colorado, should be contacted for additional information about the Controller and/or Solarstat.

## APPLICABLE DOCUMENTS

1. CR 150771 Solar Control Design Package
2. CR 150743 Installation Package for 77-180 Solarstat and 77-171 Controller
3. CR 150593 Modular Control Subsystems for Use in Solar Heating Systems for Multi-Family Dwellings
4. Proceedings of the first workshop on the Control of Solar Energy Systems for Heating and Cooling, May 1978, pages 193-195, "Government Role in Development of Microprocessor Control Systems for Solar Heating and Cooling," by James D. Hankins, Marshall Space Flight Center, Huntsville, Alabama.

Documents 1, 2, and 3 can be obtained from the Department of Energy Technical Information Center (TIC), Oak Ridge, TN. Document 4 was published by the Publishing Office of the American Section of the International Solar Energy Society, Inc. McDowell Hall, University of Delaware, Newark, Delaware 19711.

## APPROVAL

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The information in this report has been reviewed for technical content. Review of any information concerning the Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report in its entirety, has been determined to be unclassified.



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